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BUILDING ESTIMATING.

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To the architect or contractor, the matter of systematic and efficient estimating is of as great, if not greater, importance as that of efficient carrying on of the actual work of construction. The following discussion is intended to serve as a guide to the less experienced estimator on work such as is referred to, and will also provide some helpful hints for the more experienced estimator who wishes to decrease the probability of error in making estimates.

Speaking generally, the more detailed the form of estimate is made, the less likelihood there will be of error due to assumptions. Furthermore, errors, when they do occur, are more easily detected, and the estimator is able to verify his data more intelligently and systematically.

METHODS OF ESTIMATING.

The methods of estimating depend on the degree of accuracy required, and also on customs, which vary to a certain extent in different parts of the country; but we may say there are five outstanding methods of ascertaining the value of a building before erection. These methods are:

(1) **Estimating by the Cost per Cubic Foot of Similar Buildings.**—This is the best known and most usually adopted method, because of its general convenience. The dimensions are best taken by measuring the length and breadth from out to out of walls, and the height from half foundations to half-way up the roof. The cubic contents thus obtained are multiplied by the price per foot cube of some similar building. Sometimes the height is measured from the bottom of footings (i.e., top of concrete) to half-way up the roof. Cheaper attached structures, such as annexes, stables, sheds, etc., should be kept separate and priced at a lower rate; while more ornamental portions, like towers and porches, would be valued higher than the main block. Small buildings cost more, in proportion than large ones of the same type.

This cubing system is open to some objections. The lumping together of voids and solids at one rate is certainly unscientific, for the same class of building may be divided into many rooms, with numerous internal solids in the shape of walls, etc., between; while another may have comparatively few chambers, creating much empty space. In fact, the proportion of voids to the solid structure is not a fixed quantity, so that the price per cubic foot can never be exactly regulated. This requires large experience and a nicety in pricing which the estimator cannot always possess. The description and quality of materials and workmanship, too, are seldom the same; neither are the conditions of contract; and these variations are frequently overlooked when a certain rate per cubic foot is assumd.

(2) **Taking Out Rough Quantities and Pricing the Items.**—This is, of course, more exact than pricing per cubic foot because more items are considered.

(3) **Estimating per Square.**—This mode is to take the constructional shell only, and pricing it at so much per 100 square feet. Walls, for instance, are taken according to their thickness and manner of finishing, including all digging, concrete, plastering, papering, etc.; floors, including joists, struttings, ceilings, etc.; roofs, including slating, lead-work, rafters, boarding, etc.; and so on,—all being reckoned as per square complete. Such a system of superficial measurement appears to be more satisfactory than the cubing, as it takes into account the materials and labor in a more exact and definite form. Of course, a special list of prices must be compiled for each of these main superficies, and care and discrimination are certainly required.

(4) **Pricing per Unit of Accommodation.**—This is a somewhat rough-and-ready means of estimating the cost of such buildings as hospitals, schools, churches, stables, and other edifices, which may be respectively priced at per patient, per scholar, per sitting, and per horse. It is better, however, to check and approximate estimate by working out two or more styles, thereby insuring closer results.

The above methods are never used by the contractor who puts up the building, because it would be unwise, as well as unbusinesslike for him to use such loose methods. They, however, are accurate enough for architects and insurance companies, who only require an approximate figure on the value of a building.

(5) **Estimating by Accurate Quantities.**—This method is only adopted when it is intended to actually carry out the work. It is very laborious, and necessitates great skill and a thorough knowledge of building construction. This is the only method contractors can use with safety. It is intended to discuss this method fully, as it is by far the most difficult.

There are so many different trades and such a great many different kinds of material required to put up a building that, in order to make an accurate estimate, the different trades should be kept separate, as well as the different materials. There are about fourteen distinct kinds of work on a building. These are:

1. Excavation.
2. Concrete Work.
3. Masonry.
4. Brick-work.
5. Carpentry.
6. Roofing.
7. Plastering.
8. Joinery.
9. Hardware and Ironwork.
10. Heating and Ventilation.
11. Plumbing.
12. Painting.
13. Glazing.
14. Steel Work.

Space will not permit, as before stated, discussing each one of these fully, and we will therefore limit ourselves to the five of the most important kinds of work, namely: excavation, concrete work, masonry, brickwork, and carpentry. The steel work is now a very important part of the modern building, but it is such a large subject in itself that it canont be discussed here on account of lack of space.

EXCAVATION.

Before figuring on excavation, there are many things to be taken into consideration, which vary in different localities.

(a) **The Character of Material to Be Excavated.**—Where the excavation is deep, the nature of the earth's crust is liable to vary considerably, which would affect the cost of excavation to a more or less extent. Care should therefore be taken to determine the nature of the soil. If there is rock, it, of course, requires blasting. If the work is to be done in the winter, allowance should be made for blasting the frozen ground. Wet ground, which would require pumping, should not be overlooked. Sometimes it is necessary to sink caissons on account of quicksand.

(b) **The Disposition of the Material.**—The excavated material is either wasted on the premises or hauled away. If it is to be hauled away, the distance and the method of hauling should be taken into account.

(c) **Amount to Be Excavated.**—The existing levels of the ground, compared with those required, should not be forgotten. In excavating for a foundation, the excavation should be sufficiently large to give the men a chance to put up the forms.

(d) **Materials Required for Excavating.**—It is often necessary to drive piles to which to nail the lumber. The lumber and piles are to be considered in the general expense.

(e) Consider the cost of labor and the efficiency of laborers and machinery.

(f) Consider depreciation of plant.

(g) Consider office expenses.

If none of the above things are forgotten, the estimator should be able to estimate the cost of an excavation fairly accurately, with experience.

CONCRETE WORK.

The things which affect the cost of concrete work are:

1. Material.
2. Labor.
3. Overhead expenses.
4. Office expenses.

I. Material.

(a) There are five distinct types of concrete, namely: stone concrete, gravel concrete, concrete floors, concrete blocks, and reinforced concrete. In stone concrete the size of the coarse aggregate should be determined. When this is known, the cost will depend on local conditions. Sometimes the broken stone is delivered on the job at so much per cubic yard; but in some cases a stone crusher is used on the premises. The price of gravel depends on how far it has to be hauled. Frequently this can be delivered to the work for a certain price per cubic yard. For cellar floors the broken stone is first laid uniformly with a thin coating of cement on top. The cost of these floors depends on the proportion of the mixture of cement, as well as the cost of the stone. When concrete blocks are used, of course the cost of the mortar must be taken into consideration, as well as the cost of the blocks. The price of these blocks depends on the size, the composition, and whether they are moulded on the job or delivered there by the manufacturer.

(b) Another thing to be considered is the price of the lumber required to make the forms, and the centering required to support concrete slabs. If the centering can be used over again, the cost of the lumber will certainly be less than if special centering had to be constructed for each floor. The same can be said of lumber used a second or third time for simple forms. Each time the lumber is re-used, a percentage is generally deducted from the original cost. The fineness of the surface required for the concrete should not be overlooked, because this affects the price of the forms. Planed lumber is then required, when in some other cases rough lumber would do.

(c) The cost of reinforcing material depends on the kind required. If patented fabricated steel is used, the cost of same can be obtained in the catalogues. Occasionally a patent reinforcement is manufactured at the works, and a royalty is paid to the party holding the patent. The reinforcing rods, which may be round or square in section, or deformed, generally cost so much per pound. An estimator should never forget the cost of delivering these rods to the work, for the cost per pound may be the cost on the cars or at the factory.

(d) The practice regarding openings in walls, such as doorways, arches, etc., varies, and the understanding in this regard between the architect and the contractor should be observed. Small openings, however, are generally disregarded in estimating the volume of the concrete, if it is to be paid for by the cubic foot.

II. Work.

The cost of mixing concrete depends on the method, and the contractor should take into consideration whether he will use a mixer or whether the mixing should be done by hand. The concrete mixer reduces the cost of mixing per cubic yard, and if the job is large, it pays to use the mixer. All mixers, however, have not the same efficiency. Therefore, the kind used and the expense of using it, along with its capacity for work, are things to which the estimator should pay particular attention.

MASONRY.

Masonry is sometimes measured by the perch or by the cord, but the best method is by the cubic yard. In estimating by the perch, it is necessary to state how much the perch is taken at, whether 24¾ or 25 cubic feet. Note should always be made in regard to corners, and deduction for openings under a certain size. Corners are generally measured twice.

Rough stone from the quarry is generally sold under two classifications, namely: rubble and dimension stone. Rubble consists of pieces of irregular size, such as are mostly obtained from the quarry, up to 12 inches in thickness by 24 inches in length. Stone ordered of a certain size, or to square over 24 inches each way, and to be of a particular thickness, is called dimension stone.

Rubble masonry and stone backing are generally figured by the cubic yard. Dimension-stone footings are measured by the square foot, unless they are built of large irregular stone, in which case they are measured the same as rubble. Ashlar work is always figured by the superficial foot; openings are usually deducted, and the jambs are measured in with the face work. Flagging and slabs of all kinds, such as hearths, treads for steps, etc., are measured by the square foot; sills, lintels, mouldings, belt courses and cornices by the linear foot; and irregular pieces by the cubic foot. All carved work is done at an agreed price by the piece.

For estimating purposes, stone may be divided into two classes: soft stone, such as the sand stones, and hard stone, such as the granites.

Soft Stone.—Indiana limestone may be taken as an example of soft stone. The method of estimating the cost of this soft stone is to estimate so much per cubic foot for the rough blocks, and the cost of sawing, pointing, cutting, rubbing, and waste in stock is added on. If the work is tooled, which is preferable for this material, a suitable percentage should be also added.

Consoles, dentils, panellings, and similar ornamental work, mantels and exterior work, have no fixed prices, but must be governed by the estimator's knowledge of time required to cut any particular kind. If mouldings are deeply undercut, an extra price will have to be charged.

In heavy work, where the amount of stock is large, compared with the amount of dressing, deductions may be made that sometimes amount to as much as 20 per cent. Rock-face work is somewhat more expensive than plain dressed work, because the projecting rock surface requires more stock. Therefore a percentage should be added.

It is customary to leave stone roughly cut to shape for carving in the wall, and therefore the sculptor determines the value from the drawings, and includes the cost of models, which must be approved by the architect before the work is cut. Circular work, if plain, costs about the same as square work; but if fluted, as in the case of columns, it may cost as much as 50 per cent. additional.

Granite.—Final estimates of cut granite by the cubic foot are seldom made, although approximate estimates are often made in that way by comparing a proposed piece of work with a similar one already completed. The reason for not making final estimates is that every additional moulding or break in granite work affects the cost considerably, differing greatly in this respect from soft stones.

Machinery is used extensively in cutting plane faces in granite, and also to some extent for mouldings and carved work. Every line in granite is costly to cut and must be computed separately. For instance, a plane face 12 inches wide, if cut by machinery, would cost much less per square foot than if cut by hand, where the machine cannot be used. A bevel will cost so much per lineal foot additional. A scotia or other moulding will cost even more per lineal foot additional for each member. All returns, no matter how small, must be counted as not less than 1 foot. Flutes or reeds in columns are very expensive, and must be calculated in each case according to the width and depth. All notches ar rabbets are counted separately according to shape and size. Polishing plain surfaces costs so much per square foot, in addition to the cost of cutting, surfaces having widths of 4 inches and under counting as 6 inches, and those over 6 inches up to 12 inches counting as 1 foot.

Brickwork.—Brickwork is generally estimated by the thousand bricks laid in the wall, but measurements by the cubic yard and the perch are also used. The following data will be useful in calculating the number of bricks in a wall: For each superficial or square foot of wall, 4 inches (the width of one brick) in thickness, allow seven and one-half bricks; for a 9-inch (the width of two bricks) wall count 15 bricks; for a 13-inch (the width of three bricks) wall allow 22½ bricks; and so on, estimating 7½ bricks for each additional 4 inches in thickness of wall. The preceding figures are for bricks about 8½ in. x 4 in. x 2½ in. in size. If smaller bricks are used, the thickness of the walls will be decreased proportionately.

If brickwork is estimated by the cubic yard, allow 500 bricks per yard. This figure is based on the use of bricks of the size just given, and mortar joints not over 3/8 of an inch thick. If the joints are 1/8 inches thick, as in face brickwork, one cubic yard will require about 575 bricks. In making calculations of the number of bricks required, an allowance of, say 5 per cent., should be made for waste in breakage, etc.

Rubbed and ornamental brickwork should be measured separately and charged for at a special rate.

Data on Brickwork.—The following estimates on the cost of brickwork, which were very carefully compiled in the I.C.S. library, will be of value. It should be understod that the prices will vary with the cost of materials and labor; the proportions, however, will be constant. The figures are based on kiln or actual count; that is, with deduction for openings. When the work is measured with no deductions for openings, the cost per thousand may be assumed as about 15 per cent. less than the prices given, which are exclusive of scaffolding, hoisting and builder's profits. The scaffolding will cost according to the conditions of the structure and site from 5 to 7 per cent. of the prices given.

COST OF COMMON BRICKWORK PER THOUSAND BRICK, USING 1 TO 3 LIME MORTAR.

1,000 bricks	$8.00	
2 bushels of lime @ 25c. per bushel	.50	
1/2 cubic yard sand @ $1.50 per cu. yd	.75	
Bricklayer, 8 hrs. @ 55c. per hour	4.40	
Laborer, 8 hrs. @ 25c. per hr	2.00	
Total		$15.65

USING 1 TO 3 PORTLAND CEMENT MORTAR.

1,000 bricks	$8.00	
1 bbl. of Portland cement	2.00	
1/2 cubic yard of sand	.75	
Bricklayer, 8 hrs. @ 55c. per hr	4.40	
Laborer, 8 hrs. @ 25c. per hr	2.00	
Total		$17.15

USING 1 TO 4 LIME-AND-CEMENT MORTAR.

1,000 bricks	$8.00	
3/4 bushel of lime @ 25c. per bu	.19	
1/2 cu. yd. of sand	.75	
2/3 bbl. of cement @ $2.00 per bbl	1.34	
Bricklayer, 8 hrs. @ 55c. per hr	4.40	
Laborer, 8 hrs. @ 25c. per hr	2.00	
Total		$16.68

Estimating Brickwork.—The following figures and method of estimating brickwork were supplied by an estimator of a large contracting firm. The prices given include office expenses and builder's profit. The wages per hour on which these figures were based are: Bricklayers, 65 cents; hod-carriers, 25 cents; and common laborers, 18 cents.

Following are mentioned four distinct classes of brick buildings, and in the table are given the labor prices per thousand brick for the various storeys of buildings of these classes.

1. Absolutely plain factory buildings.
2. Factory or office buildings, broken up with a few pilasters and other projections; stretcher-brick facing; neatly cleaned down and pointed.
3. Office buildings of fairly ornamental type; well broken up with pilasters, projecting courses, etc.; with pressed brick facing.
4. Highly ornamental brick buildings; moulded cornices, pilasters, raised quoins, sunk moulded panels and numerous flat and segmental arches.

LABOR PRICES PER THOUSAND BRICK FOR FOUR CLASSES OF BRICK BUILDINGS.

Part of Building.	Class 1.	Class 2.	Class 3.	Class 4.
Basement	$7.50	$7.50	$8.50	$9.50
First floor	8.00	9.00	10.50	13.50
Second floor	8.50	10.00	11.00	14.00
Third floor	9.00	10.50	11.50	14.50
Fourth floor	9.50	11.00	12.00	15.00
Fifth floor	10.00	11.50	12.50	15.50
Sixth floor	11.00	12.00	13.00	16.00

The prices in the table include the cost of mortar. If the cost of brick at building is added, the result will be the total cost of brickwork, exclusive of scaffolding.

The following miscellaneous brick prices, including labor and mortar, but not brick, are from the same source as the prices given in the above table, and are based on the same conditions, the prices being in bricks per thousand:

For heavy basement walls and similar masses of brickwork.	$7.00
For 18-inch brick walls, not over 2 or 3 storeys high, in hard brick, with struck joints	8.00
Same as above, but for 13-inch walls	9.00
For 18-inch brick walls as above, but faced on one side with pressed brick	12.00
For 18-inch brick walls as above, but faced on both sides with pressed brick	16.50
For 13-inch brick walls as above, but faced on one side with pressed brick	14.00
For 13-inch brick walls as above, but faced on both sides with pressed brick	19.00

Add to above, if of English or Flemish bond, an entire cost of wall	.50
If broken up into light piers, requiring a lot of plumbing, add to cost of wall as above	1.50
If a large number of segmental arches must be turned, add to the total cost of the wall	1.00

In addition to the preceding schedule, two useful rules to remember are: For pressed brick segmental arches, add for labor 1½ times the cost of bricks; for pressed brick arches, requiring radial brick, add for labor twice the cost of straight pressed brick. As radial brick are shipped to the building in barrels, and have to be unpacked and laid out on the full-sized diagram on the floor, it will be found that the rate given is not excessive.

For brick vault arches, the cost of labor, exclusive of mortar, will be about $5.00 per thousand brick. If pointed underneath, 7 cents per square foot will have to be added. If the centres are left in place until the mortar has set, it will be necessary to rake out the joints and wet them before pointing. This will cost about 10 cents per square foot.

TERRA-COTTA WORK.

Terra-Cotta Floor Arches.—The cost of terra-cotta floor arches varies somewhat with the span and with the difficulties encountered in putting up and removing the centering. If the building consists of a number of storeys, the centering that is used on one floor may be used on a floor several storeys higher up, in this way decreasing the outlay for centering, as in the case of concrete. For ordinary spans, for instance, the following method is the ordinary way of estimating the cost of a 12-inch arch:

Centering	So much per square foot of arch.
Hoisting and Laying	So much per square foot of arch.
Mortar	So much per square foot of arch.

If the ceiling is much broken up by girders, the price per square foot of each will of course become more than if the ceiling is flat.

Terra-Cotta Partitions.—In office buildings, terra-cotta partitions are usually erected on top of a floor in order to divide the space into such rooms as will suit the tenants. This work is generally done after the work is otherwise completed. The thing to be taken into consideration in estimating the cost of such partitions are: thickness of partitions, cost of setting per square foot, including mortar, and the cost of terra-cotta per square foot.

Although not always of brick or terra-cotta nature, it will be found more convenient to consider all tiling together and at the same time that the cost of brickwork is taken up. The cost is generally taken as per square foot laid in place.

CARPENTRY.

Carpentry should include general framing, roofs, floor joists, partitions, sheathing, flooring, furring, and plastering grounds.

Studs.—To calculate the number of studs, set on 16-inch centres, the following rule may be used: From the length of the partition in feet, deduct one-fourth, and to this result add 1. Count the number of returns, or corners, on the plan, where double studding is required, and add 2 studs for each such return. (The reason for adding 1 is to include the stud at the end, which would otherwise be omitted.) The sills, plates and double studs must be measured separately.

Sheathing.—To calculate sheathing or rough flooring (not matched), find the number of feet B.M. required to cover the surface, making no deductions for door or window openings, because what is gained in openings is lost in waste. If the sheathing is laid horizontally, only the actual measurement is necessary; but if it is laid diagonally, add a certain per cent. to the actual area.

Flooring.—In estimating matched flooring, a square foot of 7/8-inch material is considered to be 1 foot B.M.. If the flooring is three inches or more in width, add one-quarter to the actual number of board feet, to allow for waste of material in forming the tongue and groove; if less than three inches wide, add one-third. Flooring of 1 1/8-inch finished thickness is considered to be 1 1/4 inches thick, and for calculating it the following rule may be used: Increase the surface measure 50%. (This consists of 25% for extra thickness over one inch and 25% for waste in tongueing and grooving.) To this amount add 5 per cent for waste in handling and fitting. In figuring the area of floors, openings for stairs, fireplaces, etc., should be deducted.

Weather Boarding or Siding.—In measuring weather boarding or siding, the superficial or square foot is usually employed. No deduction should be made for ordinary window or door openings, as these usually balance the waste in cutting and fitting.

Careful attention must be given for the allowance for lap. If 6-inch, nominal width (actual width 5 5/8 in. siding, laid with 1-inch lap, is used, add one-quarter to the actual area of the space to be covered, in order to obtain the number of square feet of siding required. If 4-inch stuff is used, add one-third to the actual area. When, as previously noted, no allowance is made for openings, the corner and baseboards need not be figured separately.

Cornices.—As a general rule, cornices are measured by the running foot, the moulded and plain members being taken separately. A good method of figuring cornices is as follows: Measure the girth or outline, and allow so much for each inch of girth per lineal foot. This price should pay for material and setting.

Cost per Square Foot.—For all classes of materials that enter into the general framing and covering of a building, a close estimate may be made by analyzing the cost per square foot of surface, that is the cost of labor and materials—studs and sheathing in walls, joists and flooring in floors, etc.—required for a definite area should be closely determined, and this cost divided by the area considered will give the price per square foot. If the corresponding whole area is multiplied by the figure thus obtained the result will, of course, be the cost of that portion of the work. While the usual custom is to adopt a uniform rate for the various grades of work, a careful analysis will show that roof sheathing, where the roof is much cut up, costs more in place than wall sheathing, owing to its position; also that the studs in walls and partitions cost more than floor joists, as they are lighter and require more handling.

Miscellaneous Carpentry Items.—There are several miscellaneous items in carpentry that require consideration. Some of these are:

Setting window panes in wooden buildings, estimated at so much apiece.

Furring brick walls, 1 in. x 2 in. strips, 16-inch centres, at so much per square foot, including labor, material and nails.

Cutting holes and fitting plugs in brick walls at so much each.

Setting window frames in brickwork at so much each.

Setting window and door frames in stonework at so much each.

Furnishing and setting trimmer-arch centres at so much, etc.

Smaller items, such as nails, etc., should also be taken into consideration.

TAKING OFF QUANTITIES.

Although the method of taking off quantities of materials from the plans have, in some cases, been explained, it may be wise to say a few general words in this regard.

Before the estimator can intelligently take off quantities from a plan, he must understand the plans perfectly. He must be thoroughly familiar with the problems of the different trades which come up in that particular building. He must know the relation of the trades to one another. In other words, while at such work, the estimator should have the exact construction of the work in his mind's eye, and must imagine the work going on, at the same time having a perspective mental view of the whole work from start to finish. The costs of material and of labor are items which change from time to time, and which, by means of a good office system, can be at the finger ends of even an inexprienced estimator; but to be able to analyze the construction of a building quickly and accurately, and to recognize the new problems which frequently come up in a building, is an asset that only the experienced builder and estimator possess.

W. F. B. Rubidge, '10, is resident engineer on the construction of the Rosedale section of the Bloor Street viaduct for the Dominion Bridge Co., who are general contractors.

CLASS OF 1910 HOLD A REUNION.

On Thursday, 26th, about forty members of Class '10 held their first reunion dinner in Toronto at the Hotel Mossop. Besides members of the class resident in the city, there were representatives from many outside points, including Winnipeg, Hamilton, Niagara Falls, St. Catharines, Campbellford, London and other places. An excedingly enjoyable time was spent, the ceremonies of the event being presided over by Geo. G. MacLennan, the President of the year. He was assisted in making arrangements for the reunion by a committee consisting of J. H. Craig and J. M. Gibson.

The guests of the evening included Lieut. E. G. MacKay, with the 38th Regiment of Brantford, with the second overseas contingent. Music was provided by Messrs. Bennett, Allen and MacLean, graduates of Toronto, and several vocal numbers were rendered by Mr. J. H. Craig.

The toast list was headed by "Our King." "The Army" was proposed by Mr. Craig, and responded to by Lieut. E. G. MacKay, who will shortly leave for the front. Reference was made to the men of the class who are now with the First Contingent, viz.: F. T. Nichol, J. G. Helliwell, W. J. Baird, A. G. Code, and M. B. Watson, and to the following men with the Second Contingent: E. G. MacKay, D. J. Miller, J. I. McSloy, A. H. Munro, and H. J. MacTavish, and also to J. M. Duncan, who has a commission on H. M. S. "Victory" in the British Navy.

The toast to the "University of Toronto" was attended to by A. V. Delaporte and J. T. King. Athletics were toasted by L. A. Wright and Hugh Gall. The health of Class '10 was proposed by Geo. G. MacLennan, and a general discussion of school affairs followed. J. M. Gibson and W. P. Dobson looked after the toast to "The Profession." Reference was made to the deaths of N. G. H. Burnham, J. N. Leitch and T. Walton since graduation.

After the welfare of the Class and the Profession had received a thorough milling, and the history of the years since graduation had been well disseminated, it was decided to hold informal luncheons each year in Toronto in October and December, to be followed by the Annual Reunion Dinner later in the winter.

A request was made that all the men who had changed their addresses since the last appearance of their names in the Directory of the Alumni in "Applied Science" should keep the President posted of new addresses in order to keep the entire year in touch with each other. The gathering dispersed with a generous rendering of "Auld Lang Syne" and "Toike Oike."

R. M. Walker, B.A.Sc., '10, formerly with Walter J, Francis & Co., Montreal, is now with G. D. Jenssen & Co., consulting engineers, Hawkesbury, Ont., who make a specialty of sulphite mills.

*FINDING THE EQUATIONS OF CURVES AND THEIR USES ON SPECIAL SLIDE RULES.

F. Gordon Reid, '15.

The end of very much mathematics, and the work of many eminent men, has been the simple and, as far as possible, accurate description of the things in the world around us.

In science there are many laws which describe the actions of certain variables with respect to others, and the actions of these variables can nearly always be shown by means of graphs or curves, which therby give us a picture of their operations which is much clearer than if we were given the actual law which described their actions.

However, it is oftentimes desirable that we know the laws which represent the actions of the variable, even if we have the exact curves of their variations given.

It is very desirable that the laws of certain phenomena be known to us, for when we have these laws in a concrete form we can apply the processes of mathematics to them, and, although mathematical processes are often mechanical, we arrive at very comprehensive, reasonable and entirely usable results which are very useful.

For instance, from knowing the laws of the universe we can predict certain future events—in fact, we may and do publish the Nautical Almanac for many years ahead of time, and thereby render invaluable aid to navigators. Similar instances may be drawn from other branches of science, and it is the method of arriving at and using this information which I wish to describe to you.

Study and the association with certain men have made me believe that problems, heretofore placed under the head of ''Rule of Thumb'' for solution, even by engineers, are capable of accurate solution.

In the Transactions of the American Society of Mechanical Engineers there is a paper entitled ''On the Art of Cutting Metals,'' by Frederick W. Taylor, and also a paper entitled ''The Transmission of Power by Leather Belting,'' by Carl G. Barth. In both of these papers a problem by many considered to be so complex and to contain so many varnables as to be completely unsolvable (accurately), is investigated and brought to a clear, accurate solution. And the solutions for the case of maximum efficiency in each case have been of great value to humanity, for you will concede that anything done efficiently is of value to humanity—that is, if the thing must be done.

Considering now one of the problems solved in the former of these papers, we will see the nature and usefulness of such an investigation:

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*Presented before the Mechanical and Electrical Club of the University of Toronto Engineering Society, on Feb. 2nd, 1915.

The Problem of a Lathe in the Act of Cutting Metal from a Forging.

Let us assume now that all details of this lathe are known—i.e., speeds available, feeds and torque available, and that the lathe is properly proportioned for rigidity; also let us assume that we are using a tool whose properties are known to be best adapted to cutting metal from the kind of forging being used.

Then the questions which present themselves to us are: What speed, feed and depth of cut should we use to remove the metal most economically? This question has for years been answered by machinists from what they call their fund of experience—but which is really "Rule of Thumb." But since you have each seen many different answers for these problems, it must have occurred to you, "Just what is the right answer?"

These questions have been answered, and the method of arriving at these answers was as follows:—

Experiments were made to show the effect on cutting speed of the variables, depth of cut, amount of feed, and the variables which these two govern—i.e., area and thickness of the shaving, and the pressure of the chip on the tool. The results of these experiments were represented graphically by means of curves and then came the question of how to use this knowledge to obtain the answer desired.

The equations of the curves were found, so that instead of having the results in the form of curves, they were now in the form of algebraic equations, and these equations were operated upon by the processes of mathematics to show the relation of one law to another, and to finally solve these relations so as in each case to arrive at the answer fulfilling the conditions for maximum efficiency.

Algebra, without the method of "Trial and Error," would not accomplish this result, but finally Mr. Barth devised a form of special slide rule, which embodied all the laws, and which in itself embodied a visual form of "Trial and Error" method, thereby arriving at the desired answer.

This was in general the method of attacking the problem, so now let us see the details, the first of which is

The Method of Finding the Equations of Curves.

The ancient Greeks studied very carefully what we now know as conic sections, and with which all are familiar in the form of the ellipse, hyperbola, parabola, and circle.

These curves all follow the general form of the equation of the second degree, and which is for rectangular axes,

$$ax^2+bxy+cy^2+dx+ey+f=0$$

the values of the coefficients being changed to give the desired curve.

Since there has been much written about these curves, and also about that class of curves called Harmonics—a particular case of which is the "sine wave"—I will not deal with methods of finding their solution here, for one may find complete analyses of these curves in text-books.

However, another type of curve which expresses many of the phenomena of science has an exponential equation, the general form of which is

$$y=kx^n$$

and since these curves plot as a straight line on logarithmic co-ordinates their solution is comparatively easy; also this type of equation is the form most easily applied to the special slide rule, which is itself very useful, so we might say that they are among our most useful classes of curves.

Consider now a logarithmic scale—that is the, the familiar graduations of a slide rule.

The length from 1 to 10 is so divided that any length x measured from 1 on this scale reads by the graduations the value of $\log_{10}x$.

Then a straight line plotted on logarithmic co-ordinates will have its equation found as

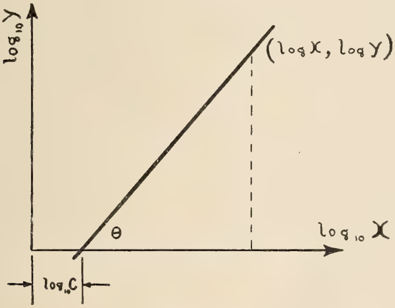


FIG. 1.

$$\frac{\log y}{\log x-\log c}=\tan\theta$$

since $\log c$ and $\tan\theta$ are constant for the curve in question

$$\text{let } \tan\theta=n$$

$$\text{and } c^{-n}=k$$

$$\text{then } \log y=n\left(\text{og}\,\frac{x}{c}\right)$$

$$\text{or } y=x^n\,c^{-n}=k\,x^n$$

Similarly for another case

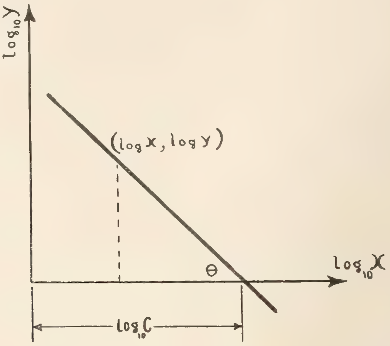


FIG. 2.

$$\frac{\log y}{\log c - \log x} = \tan \theta$$

letting $c^n = k$ and $\tan \theta = n$ then $\log y = n\left(\log \frac{c}{x}\right)$

$$\text{or } y = c^n x^{-n} = \frac{k}{x^n}$$

this method of solution has been applied to the curves whose equations are given in Figures 3, 4, and 5.

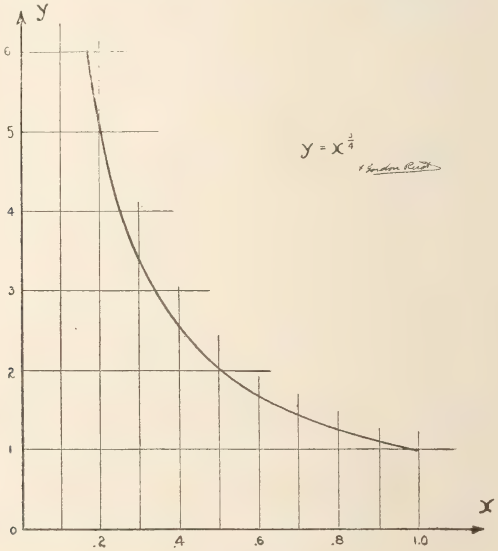


FIG. 3.

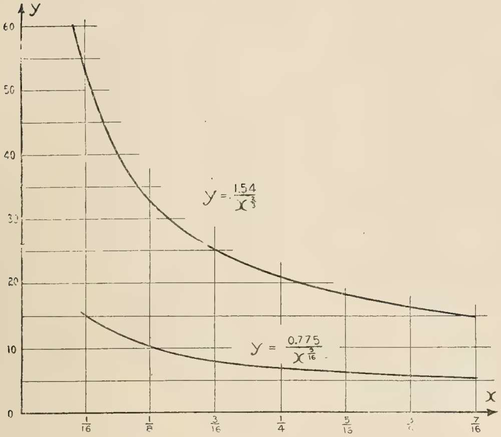


FIG. 4.

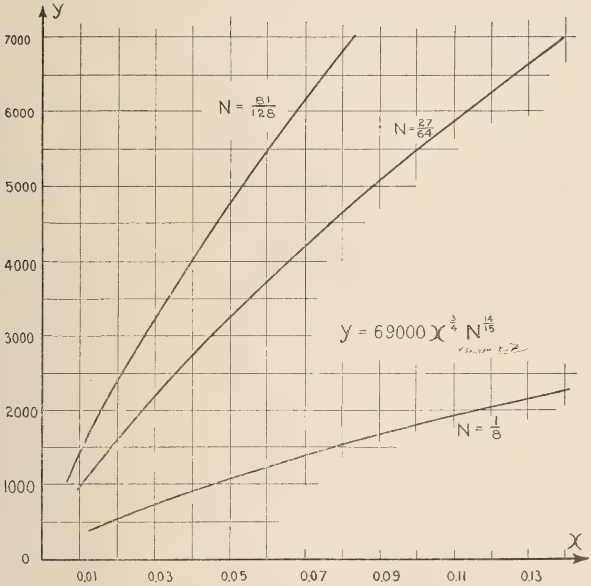


FIG. 5.

Some general headings, and points may now be laid down as follows:—

Having plotted the curve for which we desire to know the equation, we decide

1. If the curve looks at all like the expansion of steam or air adiabatically; that is, the expansion line on an indicator card, it is well to try plotting it on logarithmic paper and see if the points

lie approximately in a straight line. If so, the solution is carried out as described. Fig. 1 or Fig. 2.

If the curve when plotted on logarithmic paper forms the arc of a circle, then proceed as in above case, but from analytical geometry substitute the circle equation for that of the straight line as used above. A little study will show how this may be accomplished.

2. If the curve appears like any "conic section," i.e., hyperbola, parabola or ellipse, use the equation given earlier in the paper, and proceed as follows: For corresponding points of x and y insert their values in the equation (note, always use more than three points), and solve simultaneously for the values of the constants.

3. If the curve does not lend itself to either of the above methods, a third of this type might be tried.

Consider the general equation as

$$y = a + bx + cx^2 + dx^3 + \ldots, \text{ etc.}$$

$$\text{or } y = a + bx + c\sqrt[2]{x} + d\sqrt[3]{x} + \ldots, \text{ etc.}$$

Three terms are generally sufficient, for the equation of the cube is seldom encountered.

Using this equation, proceed as in Method 2.

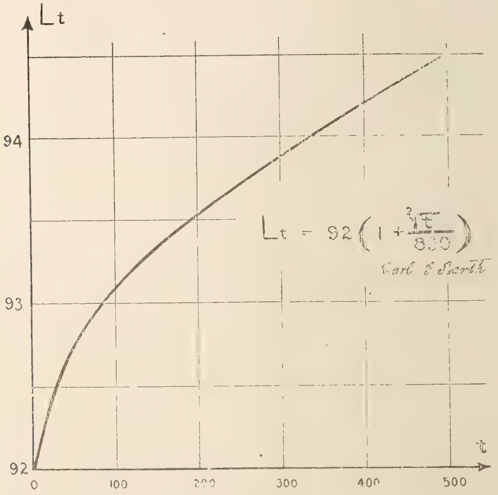


Fig. 6.

A constant factor of the value of the intercept on the axis of x or y may be brought outside a bracket in order to simplify the equation, if desired.

A practical example of this is shown from the tests on the elastic properties of leather belting by Wilfred Lewis—the equation was found by Mr. Barth, and used by him in his paper, A. S. of M. E., Trans. No. 1230, Vol. 31.

There are also other simple curves having formulae like

$$y = a - \frac{b}{c+x}$$

$$y = \frac{a}{b+x} + \frac{c}{d+x}, \text{ etc.}$$

But since I have not as yet found a general method for finding the equations of many of this type of curve, I bring it to your notice more as a suggestion for investigation in the future than as information, but since we know there is a method of finding these equations, let us hope that some of us may stumble on it in the near future and add it to the general knowledge.

There is, however, the general form of all curves, $y = f(x)$, and it would seem that this should lead us always to the result, if the following reasoning be followed:—

From the geometical significance of the derivative we know that $\frac{dy}{dx} = \tan \theta$. Now, for any curve which we have plotted we can draw the tangent at several points and find θ, and thus inserting the corresponding values of x and y we should be able to solve the equations and find what function x is of y, for in each equation the function x is of y remains constant.

However, this inverse method, which is akin to integration, is as full of difficulties as its relative, and becomes practically a "method of trial," which you will find in most cases unssuccessful.

Now, before taking up the application of these laws on the special slide rule, let us put down a few points to be borne in mind either when doing work or in reading the works of others.

Do not assume that the law derived from the curve of the experiments may be used for points outside the range of the experiment.

Always have more than three points from which to plot the curve, and it is well to use, when drawing the curve, the average of points for the same values of the variables, making the curve an average of the average points.

Do not let a theoretical perusal of the subject influence you too much in the choice of a formula to express the law shown by the curve—rather have regard to the accuracy and generality of the results.

The following is a consideration of a form of the special slide rule, which is most useful in applying the results found by the above methods—or, in fact, by any methods which lead to accurate applicable results.

The fundamental principle of a slide rule is that it algebraically adds quantities expressed by lengths on a scale. In the case of the familiar Mannheim Rule, the addition is of the logarithm of the quantity, Thus, when you perform the following:

$$3 \times 9 = 27$$

on the rule. What really is being carried out is the following:

$$\log_{10}3 + \log_{10}9 = \log_{10}27$$

With this knowledge now—consider the equation for the Specific Speed of Hydraulic Turbines

$$Ns = \frac{NP^{\frac{1}{2}}}{H^{\frac{5}{4}}}$$

in which

$Ns =$ Specific Speed
$N =$ Revolutions per Minute
$P =$ Horse Power of Runner
$H =$ Effective Head in feet on Runner.

Then a Slide Rule to embody this formula would have to perform the following

$$\log_{10}N + \tfrac{1}{2}\log_{10}P - \tfrac{5}{4}\log_{10}H = \log_{10}Ns.$$

The rule shown accomplishes the result in the following manner·

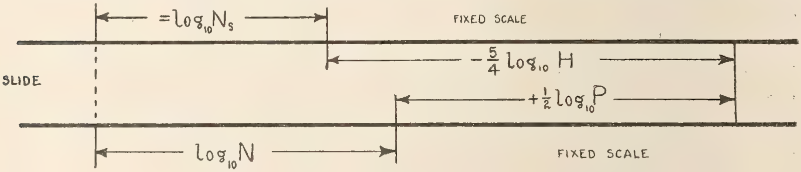
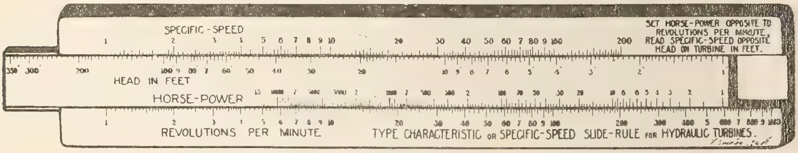


FIG. 7.

Thus, for length log n a logarithmic scale was constructed of unit length, and for length ½ log P a logarithmic scale of ½ unit length was made, etc., for H and Ns, the rule finally taking the form shown below.


SPECIFIC-SPEED
SET HORSE-POWER OPPOSITE TO REVOLUTIONS PER MINUTE, READ SPECIFIC-SPEED OPPOSITE HEAD ON TURBINE IN FEET.
HEAD IN FEET
HORSE-POWER
REVOLUTIONS PER MINUTE
TYPE CHARACTERISTIC OR SPECIFIC-SPEED SLIDE-RULE FOR HYDRAULIC TURBINES.

Two other rules have been made, which, combined with the specific speed rule, will give—

The Type of Turbine to be Used.

The Diameter of the Reaction Runner.

The Diameter of the Impulse Runner and the corresponding diameter of the nozzle or jet to be used.

These three rules practically solve any problem in the design of an hydraulic plant, and give a fair example of the applicability of the special slide rule to engineering.

The following are illustrations of the complicated formulae which have been applied to the special slide rule.

$$\theta_2 - \theta_1 = Cv \log e \frac{p_2}{p_1} + Cp \log e \frac{v_2}{v_1}$$

This is the well known 'Change of Entrophy' formula for air.

$$P = \frac{(e^{fa}-1)\ (2A - 0.00001036\,V^2)\,a}{2e^{fa}-1}$$

one of Mr. Barth's formulae for the Pull of Belts.

$$V = \frac{13.4}{F^{0.5514}\left(\frac{48}{9}D\right)^{0.3133} + \frac{7.2}{54+48D}}$$

one of F. W. Taylor's formulae for the cutting speed of standard tools on steel.

This, I believe, will show the pettiness of crticizing formulae on account of their complicated nature—for they are still simple and useful if they are applicable to the special slide rule.

A point of perhaps no little interest in connection with the foregoing is the following method of constructing a logarithmic scale by geometry.

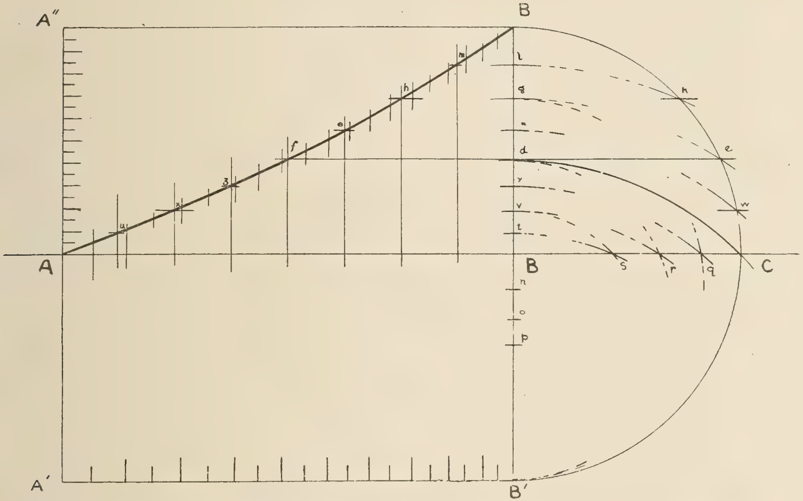


Figure illustrating the method of constructing a logarithmic curve or scale.

We have always associated the construction of logarithms with calculus, Taylor's Theorem and the value of e, but knowing the properties of a logarithmic scale should show us a method of constructing it by geometry.

For a logarithmic scale the distance from 1 to 2 equals the distance from 2 to 4, and so on, and the intermediate lengths are proportional.

We also know the simple truth that the angle in a semi-circle is a right angle, and that therefore the perpendicular from the vertex of this triangle on the base or diameter of the circle is a mean proportional between the lengths into which it divides the base or diameter.

This, then, suggests the following method of constructing a logarithmic scale.

Take A B, the desired length, and divide into 8 equal parts; erect B″ B B′ perpendicular to A B of convenient length, and construct the semi-circle B″ C B′ as shown.

Then with centre B′ and radius C B′ cut B″ at "d".

Make d, e, f parallel to B C, and with centre B′ and radius B′ e cut B′ B″ at "g".

Make g, k, h parallel to B C, and with centre B′ and radius B′ k cut B′ B″ at l.

Divide g B′ at n, and with radius n g and centre n cut B C at q, then with centre B′ and radius B′ q cut B′ B″ at y.

Divide B′ d at o, and with centre o and radius o d cut B C at r, then with centre B′ and radius B′ r cut B′ B″ at v.

Make z, v, w parallel to B C, and with centre B′ and radius B′ w cut B′ B″ at $\propto$

Divide B′ v at p, and with centre p and radius B′ p cut B C at s. With centre B′ and radius B′ s cut B′ B″ at t.

Now produce the seven points, l, g, $\propto$, d, y, v and t parallel to A B C, and the points u, x, z, f, υ , h and m where the divisions of A B and B B″ intersect will lie on a logarthmic curve from A to B″—from 1 to 2.

If now A A″ be divided into ten (10) equal parts and the points be produced parallel to A B till they intersect the curve A B″ and these points be carried down to A′ B′ parallel to B′ B″, then A′ B′ is divided as a logarithmic scale from 1 to 2.

As shown in the figure, A A″ was divided into 20 equal parts, which makes the divisions of A′ B′ a more finely divided logarithmic scale—this process may be carried to the refinement desired, giving a scale divided to as any decimals as required.

The proof of this is as follows:

(1) $B'd = B'C = \sqrt{2} = 2^{\frac{1}{2}}$ if BB' is considered as length 1

(2) $B'g = BC$ and $(B'C)^2 = (B'd)^2 + (de)^2$

$$= (B'd)^2 + (BC)^2 - (Bd)^2$$
$$= (\sqrt{2})^2 + 1^2 - (\sqrt{2} - 1)^2$$
$$= 2 + 1 - 2 - 1 + 2^{\frac{3}{2}}$$

or $B'g = \sqrt{(B'C)^2} = 2^{\frac{3}{4}}$

similarly for $B'l$

(3) Now $(B'V)^2 = (B'r)^2 = (B'B)^2 + (Cr)^2 - (CB)^2$

$$= (B'B)^2 + \left(\frac{B'd}{2}\right)^2 - \left(B'B - \frac{B'd}{2}\right)^2$$
$$= 1 + \left(\frac{1}{\sqrt{2}}\right)^2 - \left(1 - \frac{1}{\sqrt{2}}\right)^2$$
$$= 1 + 2^{-1} - 1 - 2^{-1} + 2^{\frac{1}{2}}$$

or $B'V = 2^{\frac{1}{4}}$

similar proofs being had for the other points—the complete list being as

$B'B = 2^0$
$B't = 2^{\frac{1}{8}}$
$B'V = 2^{\frac{1}{4}}$
$B'y = 2^{\frac{3}{8}}$
$B'd = 2^{\frac{1}{2}}$
$B' \propto = 2^{\frac{5}{8}}$
$B'g = 2^{\frac{3}{4}}$
$B'l = 2^{\frac{7}{8}}$
$B'B'' = 2^1$

these terms are in geometric progression with the general term as 2^{mn}
where $m = \frac{1}{8}$ and $n =$ (number of term -1).

Now it is a fact that the differences of terms in geometric progression are themselves in geometric progression—so we see that the lengths Bt, tv, vy, etc., are in geometric porgression, and that the sum of the eight lengths is unity,

$$i.e., \ (2^1 - 2^{\frac{7}{8}}) + (2^{\frac{7}{8}} - 2^{\frac{3}{4}}) + \ldots (2^{\frac{1}{8}} - 2^0) = 1.$$

With this knowledge and also remembering that for any three terms in geometric progression the middle term is a mean proportional between the other two, it is evident that by making the value of $M = \dfrac{1}{10}$ and using 10 terms of the series that we can build up a logarithmic scale from the resultant scale.

Note (the length $A'B'$ is merely the series where $m = \dfrac{1}{10}$ considering $A'B' = 1$, transformation being made from the series with $m = \dfrac{1}{8}$ by the curve AB'').

With length A′ B′ as the first unit length of a logarithmic scale, i.e., from 1 to 2, we can then repeat from 2 to 4—4 to 8 and 5 to 10, making the complete scale from 1 to 10 in that manner—thus by means of geometry alone we have constructed a logarithmic scale, and if a natural scale of the same length from 1 to 10 be laid coinincident with it, then the logarithm of any number shown on the graduations of the logarithmic scale may be read off the natural scale. This is the familiar method of finding logarithms on a slide rule.

The two points illustrated in this paper are the connecting links between experiments and the use of their knowledge in different branches of engineering—the solving of the curve finds the law, and the slide rule is a means of applying it handily.

We should rely upon the information gleaned from accurate tests rather than upon a theoretical consideration of the subject—and in many cases in engineering no amount of theorozing will show the way to solution.

With the complicated conditions and numerous variables present in the case mentioned—cutting metal on a lathe—no amount of theorozing would have obtained the result desired; it was by making accurate experiments and from the curves of these experiments finding the laws governing the variable and using these laws on special slide rules, that the efficiency of all metal cutting machinery throughout the world was so materially increased by Frederick W. Taylor and his associates.

This should illustrate the usefulness of methods of which the foregoing are examples.

LETTER FROM A "SCHOOL" MAN AT THE FRONT.

The following letter was received by his parents from Sergt. C. A. Bell, B.A.Sc., '14, who is with the 2nd Field Co., Canadian Engineers, in France:—

March 4, 1915.

Dear Parents:

Well, everything is going fine just at present. I received your letters of February 5th, a week or so ago, also several lots of papers dated about Feb. 10th.

Well, we have been in the trenches at last. We were employed building new ones and repairing old ones. The line was rather a quiet one where we were, only a few shots now and again. At first you duck and think rather fast, but soon it seems a normal part of your life, and the buzz and whir of a bullet does not bother one as much as the buzz of a troublesome mosquito. The big guns and shells make you start for a time, but unless they are close to you, one does not bother about them after a time. However, as long as you hear them you are safe, because if it does get you, you won't hear it.

Shells are the worst, and they have certainly wrecked some buildings in this part of the country. In the first place that we were in, the church used to get a few German shells each day or so. I don't think that it was intentional to shell the church, but the church spires form good range marks.

I have not seen any Germans yet, except some prisoners in a French town. One thing that impresses one about the English Tommy is that he is always shaved. They look as though they had their daily trip to the barber.

Up until now we have usually been billeted in a barn. The other day we moved and were billeted temporarily in an old farm house. We had three or four sheaves of straw, and the farmer wanted to charge us 8 francs, but of course one cannot draw blood out of stone. We have received 15 francs since coming here, and that was all gone to supplement our rations. Food is high over here in most places. One thing that is particularly good is the coffee, one penny a cup (10 centimes).

Our present billet is the best yet. It is a schoolhouse, and we are fixed quite comfortable. I am writing this before a fireplace while sitting in a big arm-chair. Also, four of us have one bed, some luxury. I will be very comfortable as long as the Germans don't drop a few shells into it.

I met Gordon Hughes to-day. He is keeping well, and has a good job now. He is dispatch rider for headquarters. He has a motorcycle to travel around on.

I suppose the winter will soon start to turn over there now. We had our hardest touch of winter the other day while on the march. The column had just stopped on the outskirts of a town for a few minutes, when up came a blizzard, which lasted for 15 or 20 minutes.

You might send me a few boxes of milk chocolate every week, also one pair of socks per week, heavy ones. You might also send a towel once a month. This will save washing and mending, besides rubber boots soon wear out socks.

Well, I must close now, as the candles are not very long.

With love to all,

(Signed) AUSTIN.

AFTERMATH OF THE DINNER.

In the report of the Annual Banquet last month, we unfortunately omitted to mention that the Class of '09 had a re-union that evening, about forty of them being present. This Class has always proven to be a "live wire," and the reunions of these men have helped materially toward the success of the Annual School Dinner. It is hoped that all the other years will soon follow their example, and thus be of real assistance in "boosting" the School and School men. Class '14 have made a good start, and also had a reunion on the night of the annual banquet, when a large number of them turned out to meet their former classmates.

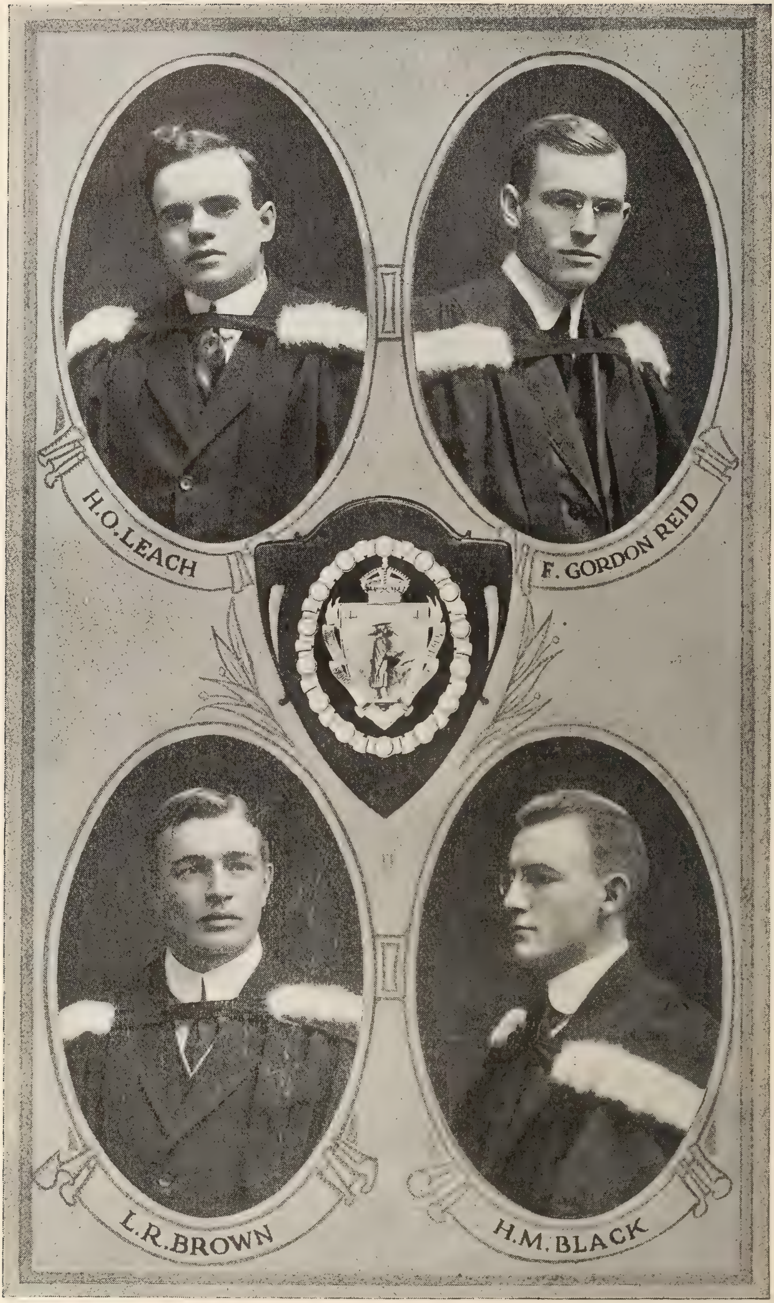
Class '10 have already had one reunion and intend to have a reunion on comparatively recent dates. The men who attend others at regular intervals. Class '08 and Class '07 have each had these reunions are unanimous in declaring that it is "worth while," and have no hesitation in recommending men of other classes to take action and get their men together.

C. C. Rous, B.A.Sc., '13, is in the Ordnance Department, 11 Haldimand Hill, Quebec, P.Q.

J. M. MacInnes, '06, is assistant engineer, Canadian Pacific Railway, Winnipeg, Man.

J. A. Mackenzie, '06, is a member of J. A. Mackenzie & Co., railroad contractors, Kerresdale, B.C.

J. C. Johnston, '00, whose home is at 1459 Mississippi Ave., Portland, Oregon, is with Warren Bros. Co., paving contractors in that city.



WINNERS OF INTER-YEAR DEBATING TROPHY, 1914-15.

A TROPHY FOR DEBATING.

Mr. W. E. Segsworth, Mining Engineer, Toronto, has presented an artitically and appropriately designed shield to the Engineering Society of the University of Toronto as a trophy in inter-year debating. It has long been felt that debating and public speaking should be encouraged among engineers, so that as a result of proper training, they would be better enabled to present their views and contentions before the various boards, etc., who receive their reports. This shield, which is of sterling silver on a mahogany background, will in future be looked upon with pride by the society, and will do a very great deal to improve the training of the young engineers at the University.

The trophy was won this year by the graduating class, who were represented by Messrs. H. M. Black, H. O. Leach, F. G. Reid and L. R. Brown.

A silver cup has also been presented to the society by a number of graduates, as a trophy in public speaking. This will no doubt assist in preparing material for the debating contests and serve as an additional incentive to greater activity along the desired lines.

ADDRESSING OF MAIL TO MEN AT THE FRONT.

In order to facilitate the handling of mail at the front and to insure prompt delivery it is requested that all mail be addressed as follows:—

(a) Rank ....
(b) Name ....
(c) Regimental Number ....
(d) Company, Squadron, Battery or other unit.....
(e) Battalion ....
(f) Brigade ....
(g) First (or Second) Canadian Contingent.......
(h) British Expeditionary Force ....
Army Post Office,
LONDON, ENGLAND.

R. E. Watts, B.A.Sc., is in the Welland Ship Canal Office at Allanburg, Ont.

J. B. Skaith, B.A.Sc., '14, is with the construction department, Toronto Power Co., Toronto, Ont.

T. L. F. Rowe, '11, is superintendent of construction, new Hospital for Insane, Whitby, Ont.

J. D. Peart, B.A.Sc., '14, is with the ToughOakes Gold Mines, Kirkland, Ont., installing electrical equipment for mine and mills.

E. L. Cousins, B.A.Sc., '06, chief engineer for the Toronto Board of Harbor Commissioners, has been granted a leave of absence for eight or nine months to undertake the preparation of plans for a system of radials and radial entrances for the city.

The following men, in addition to those previously announced in "Applied Science," have enlisted for active service:—

First Contingent—Lieut. G. L. Magann, '15, Dr. H. E. Cawley, '99, G. R. Dashwood, '16, R. D. Hague, '08, F. M. Perry, '98; D. Wilson, '15, A. H. Qua, '08.

Second Contingent—F. A. McKinley, '17, C. G. Hewson, '17, J. F. Young, '17, J. Ward, '17, C. H. Smith, '17, J. H. Legate, '17, E. B. Dustan, '17, E. S. Byres, '17, E. R. Dafoe, '17, W. R. Bauer, '17, W. B. Andrew, '17, W. H. Aggett, '17, H. B. Norwich, '16, A. R. Mendizabal, '16, A. B. Whaley, '16, C. E. Gage, '16, C. W. Edmonds, '16, W. G. Shier, '15, R. M. Arthur, '15, C. Smythe, '16, V. R. Pfrimmer, '16, F. S. Merry. '16, S. K. Cheney, '16, F. J. Matthews, '16, K. D. McDonald, '15, R. B. Sinclair, '15, C. E. Sinclair, '14, D. L. N. Stewart, '05, H. K. Wyman, '11, G. A. Cockburn, '15, J. N. Williams, '15.

Third Contingent—C. J. Inglis, '04, L. W. Klingner, '07, L. R. Wilson, '09, H. S. Clark, '10, A. W. Sime, '14, W. E. Raley, '15, W. W. Ritchie, '16.

The C. O. T. C. at the University has received the most of their uniforms, and it is expected that the remainder will be ready in a short while. A band, under the leadership of H. O. Leach, '15, has been organized to accompany the men at the concentration camp this spring. It made its first public appearance in the parade on March 20th, when over 9,000 men in uniform, including mounted rifles, infantry, cycle corps, artillery, etc., marched through the streets of Toronto, when, it is estimated, over 200,000 citizens turned out to view the inspiring parade.

W. E. Phillips, B.A.Sc., '14, is capitain in the 7th Battalion, Royal Lienster Regiment, at Fermoy, Ireland. At present he is at Camberlee, England, at the Staff College.

WANTED.

A "School" man who has passed his preliminary D.L.S. examination, for about 8 months, as assistant on D.L.S. work in Western Canada, to begin about April 10th. The work consists of making corrections and completting unfinished surveys in Manitoba, Saskatchewan and Alberta. Apply to "Applied Science" Employment Bureau.

WANTED.

"School" man, who has pased his preliminary D.L.S. examination—for period of probably eight or ten months on D.L.S. work in B. C. To begin immediately. Apply "Applied Science" Employment Bureau.

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APPLIED SCIENCE

INCORPORATED WITH

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DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE
AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

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EDITORIAL.

ENGINEERING SOCIETY ELECTIONS.

The elections of the Engineering Society and the programme of entertainment with which the occasion is celebrated have always proven themselves to be a fun factory, not only for the undergraduates, but also for the graduates who are "socially" inclined and return to assist in the ceremonies. The campaign this year furnished as keen contests as has any in the past, and a particularly pleasing feature was the unusually large number of graduates who were present at the evening entertainment, which was held in the Second Year drafting room behind Convocation Hall.

A liberal supply of fruit and tobacco and pipes was distributed to the men, who always appear to possess an unusual capacity for such luxuries on these occasions. An atmosphere of energetic and unrestrained activity pervaded the entire number, and everyone contributed some share toward the enjoyment of himself and the others. The usual dress of social events was discarded for more serviceable uniforms, as forecasts had intimated that there would be considerable work of a practical nature, in which the assistance of all present might either voluntarily or forcibly be brought into play.

Apart from the spontaneous entertainment, which was always at the point of effervescence, and ready to assert itself in a multitude of forms upon the slightest indication of a calm in the proceedings, there was a very good programme of events and contests arranged by a committee, of which Mr. K. A. Jefferson, '15, was convener.

PRESIDENT-ELECT, C. E. HASTINGS

The first event was a game of broom-ball on roller skates between the Juniors and the Seniors. The play was fast and furious, but was kept well in hand by Mr. E. M. Moneith, '15, who acted as referee. Though the game was closely contested, the Seniors won by the score of 4—2, and thereby added another championship to their laurels before graduating.

The next event, a modern chariot race, in which a team of seven men from each year was entered, was perhaps the most interesting and lively of the evening. The first heat between the Second and Fourth Years was won by the Seniors by half a lap, while the second heat was annexed by the Third Year, who just managed to nose out the Freshmen. The final heat between the two winnnrs of the former heats was won by the Fourth Year, when Mr. L. S. Adlard, by clever riding won the laurels.

Another broom-ball match was staged between the Fourth Year miners and the Fourth Year men in sanitary engineering. Owing to disputes and the uncertainty of the play, no decision was announced.

By this time most of the surplus energy had been worked off by the crowd, and everyone was satisfied to take a rest and view other items of the programme in which there were fewer contestants. The gym team, under the leadership of A. R. Mendizabal, '16, gave an exhibition, and won the appreciative applause of the spectators.

A fencing contest between L. G. Glass, '15, and J. E. Breithalpt, '15, was refereed by F. C. Mechin, '14, who gave the decision in favor of Mr. Breithaupt. The next fencing bout, which was refereed by Professor C. H. C. Wright, was won by C. E. Oliver, '16, over O. D. Vaughan, '17.

Two boxing bouts were refereed by J. M. Gibson, '10, to the entire satisfaction of even the contestants. The first encounter, between "Short" Suhler, '15, and "Slim" Krug, '16, was of a whirlwind variety, in which the short end of the fighting won the long end of the decision. The next bout was a blindfold contest, in which the outstanding contestants were the referee and F. R. Allan and E. Birdsall, the heavyweights of year '18. Mr. Allan was declared to have won the decision over his opponents.

Mr. M. B. Hastings, '10, who won the first wrestling championship for the "School" in 1909, acted as referee in a wrestling bout between J. Gray, '15, and J. E. Tremayne, '16, which was won by Mr. Gray.

The last event was a pick-a-pack wrestling match between J. Ross, '16, and G. S. Stratford, '16, comprising one team, and A. H. Livingstone, '18, and G. C. Storey, '15, comprising the other team. This match was refereed by Major Heron, president of the Argonaut Club, and T. P. Galt, K.C., honorary president of the same Club, who gave the decision to Messrs. Livingtonse and Storey.

President Gray then announced the result of the election, which showed the following to have been chosen as the Executive for next year: President, C. E. Hastings; Vice-President, W. B. Honeywell; Corresponding Secretary, R. S. C. Bothwell; Recording Secretary, J. McEachren; Treasurer, G. H. Sohn; Chairman of Civil Club, H. A. Babcock; Chairman of Electrical and Mechanical Club, T. A. Daniel; Chairman of Chemical Club, D. Boyd; Chairman of Archtiectural Club, J. L. Skinner; Chairman of Mining Club, B. A. McCrodan; Fourth Year Rep., J. R. Kirby; Third Year Rep., H. R. Nicholson; Second Year Rep., J. H. McVean; Curator, J. Gardner; First Year Rep., to be elected.

After the results had been announced speeches were given by the president-elect, Mr. Hastings, and also by the other presidential candidates, Messrs. D. G. Hagarty, S. R. Ross and W. L. Dobbin.

In response to the entreaties of those present, short addresses were delivered earlier in the evening by Prof. Wright and Mayor T. L' Church, both of whom referred appropriately to the part which "School" men are taking in the present national crisis. They complimented them on the good work which they are doing in that regard, and also congratulated them on the success of the evening's programme.

The Toike Oikestra, which had so unselfishly furnished music throughout the evenig ,played the National Anthem, and after it had been heartily sung by all present, the crowd dispersed.

PRESIDENT GRAY'S RETIRING ADDRESS.

Gentlemen:—

After a year so pleasant as you gentlemen have made it, one could scarcely, without a tinge of regret, bid farewell to such enjoyable duties.

It is indeed a pleasure, though, on behalf of the Engineering Society, to welcome you, Mr. Hastings, to this office.

Your fellow-students have conferred upon you not only the greatest undergraduate honor in their Faculty, but I truly believe in the entire University. I congratulate you.

Co-existant with that honor, Sir, is a responsibility none the less great. Time will not permit me to dwell in detail upon the varied maters demanding your attention. I venture to hope, however, your first aim shall be to consolidate such work of your predecessors as may be worthy of retaining. The Supply Department, Applied Science, the Employment Bureau, the furtherance of debating and public speaking, all want every attention. Detailed reports on these, as well as other matters, are compiled and await you.

Above all, I would urge that you ever remember that the Engineering Society consists not only of the President and Executive, but of every graduate as well as undergraduate of the "School." Do all in your power to preserve the traditions of the past, to tighten and strengthen the fraternal bond and make it still more true that, no matter where you find him, if the hand grips a little tighter and the smile's a little broader, then you'll know he's a "School" man.

Gentlemen, on behalf of the outgoing Executive, I wish to thank the Professors and the other members of the Engineering Society for the consideration and support you all have given us this year.

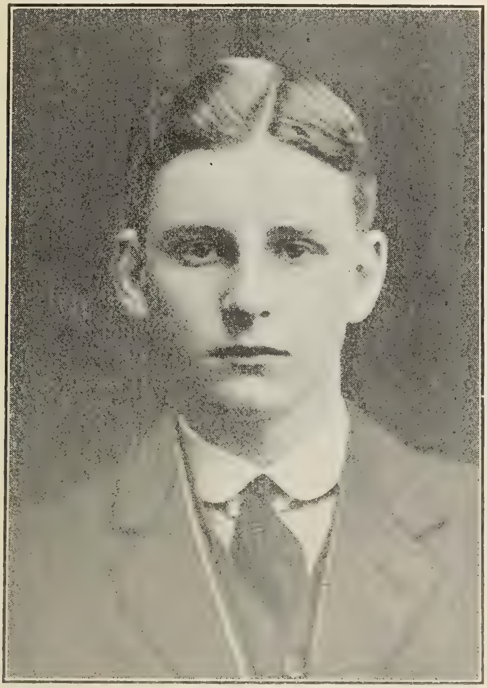
I take great pleasure in presenting Mr. Hastings, your President-elect 1915-16.

E. D. GRAY.

ROLL OF HONOR

Lieut. F. L. Eardley-Wilmot.

Lieut. F. L. Eardley-Wilmot, whose home was at Westward-Ho, Devon, England, was a son of Colonel A. Eardley-Wilmot, R.F.A., who is at present in command of one of the ammunition columns in France. He came to Canada during the summer of 1913, and entered the "School" in the department of Civil Engineering with Class '17.



F. L. EARDLEY-WILMOT, '17

During the summer of 1914 he was employed in the Public Works Department, City Hall, Toronto, and after the outbreak of the war he joined the Princess Patricia's Light Infantry, which regiment he accompanied to the front.

A letter from him, dated March 1st, stated that he had received an appointment as machine gun officer with the P.P.L.I., and that on March 4th he would be sent back from the firing line to take a two weeks' course on machine gun work. It must have been very shortly after his return to the front that he was killed in action.

Besides his father, his mother, and three sisters mourn his loss. Although he was only nineteen years of age, his worth was recognized when he received a commission with the battle-scarred soldiers of the P. P. Light Infantry.

Norman Lawless.

When the call for recruits for the First Canadian Contingent was made, among the first to enlist was Norman Lawless, who joined the 2nd Field Company, Canadian Engineers. Mr. Lawless was born in Hamilton, Ont., but his family moved to Toronto when he was quite young. He received his Public School education at Queen Victoria School, and afterwards attended Parkdale Collegiate Institute. He took a course in civil engineering at the "School" with Class '11, and since then had been employed in the sewer department at the City Hall, Toronto.

NORMAN LAWLESS, '11

After the contingent had reached England he had been transferred to a mounted regiment on account of his knowledge of horses; but later he was again placed with the Engineers, it being felt that his engineering experience rendered him too valuabl man to be removed from the Engineers' Company.

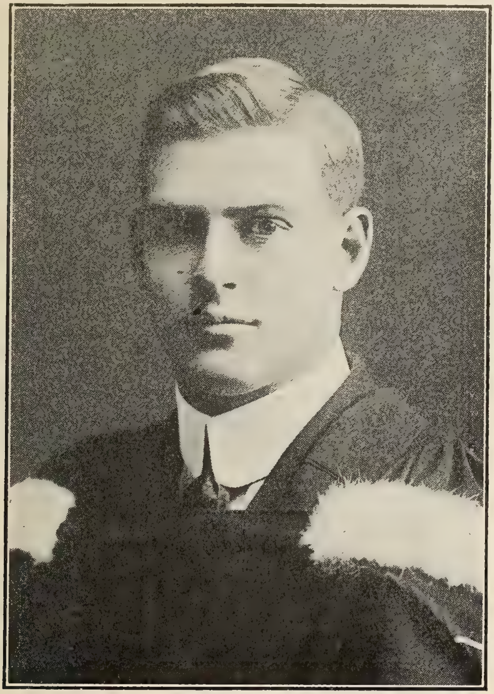
During the transfer of the Canadian troops from England to

France, Norman contracted a cold, due to exposure, which developed into acute pneumonia. He died in a hospital in France on February 19th, at the age of twenty-seven years.

His parents are both deceased, but to his other relatives we wish to express our condolence in the loss of a brother who so nobly answered his country's call and gave all he could for the cause of honor and freedom.

Lieut. Fred. C. Andrews.

Mr. Andrews graduated from the "School" with Class '14 in mining engineering. After graduation he accepted a position as engineer with the Dome Mines at Porcupine, Ont. Through an accident he had his hand injured, and as a result was at his home in Hamilton when war was declared, and was unable to accompany the First Canadian Contingent on account of the injury.



F. C. ANDREWS, B.A.Sc., '14

Feeling that it would be a long while before he would reach the front with another Canadian contingent, he sailed for England at his own expense. He secured a commission in the Second Leinster Regiment, and after a six weeks' course at Cork, Ireland, he left to join his regiment early in December, reaching the trenches on Christmas Day.

The many letters received from Lieut. Andrews by his parents and friends were very realistic in their description of operations in the theatre of war. He often referred to his appreciation of gifts received from home since he had reached the front, and always portrayd a cheerful confidence in the ultimate success of the work in which he was so active.

A cablegram was received by his father, Mr. C. H. Andrews, 26 Mapleside Ave., Hamilton, conveying the sad news that his only son had been killed in action on March 16th. Deceased was 25 years of age, and was a fine type of Canadian manhood. We wish to convey to his relatives our sympathy in their loss of one who so nobly gave his life for the country's cause.

PEAVIE.

We beg to acknowledge receipt of a copy of No. 3, Vol. I, of our contemporary, ''Peavie,'' which was published by the 2nd Field Company, Canadian Engineers, when at Salisbury Plain, England. It is devoted to articles relating to the war and to personal items of interest regarding the members of the company. Captain T. C. Irving, '06, is circulation manager. The following poem is taken from this number:—

And you, a patriot in your prime,
  You waved a flag above his head,
And hoped he'd have a high old time,
  And slapped him on the back and said:

''You'll show 'em what we British are!
  Give us your hand, old pal, to shake.''
And took him round from bar to bar,
  And made him drunk—for England's sake.

That's how you helped him. Yesterday,
  Clear-eyed and earnest, keen and hard,
He held himself the soldier's way—
  And now they've got him under guard.

That doesn't hurt you: you're all right;
  Your easy conscience takes no blame;
But he, poor boy, with morning's light
  He eats his heart out, sick with shame.

What's that to you? You understand
  Nothing of all his bitter pain;
You have no regiment to brand;
  You have no uniform to stain.

DIRECTORY OF THE ALUMNI.

Campbell, W. C., '05, whose home is at Keene, Ontario, was in the West, engaged in mining enginering when last heard from.

Campbell, A. W., '06, is with the Hydro-Electric Power Commission, Toronto.

Campbell, H. M., '14, is Lieut. Second Contingent in camp at London, Ont.

Campbell, H. A., '14, lives at 5 Schofield Ave., Toronto.

Campbell, J. E., '08, has no address with us at present, except his home address at Coldstream, Ont.

Campbell, C. D., '11, is town engineer of Galt, Ont.

Candee, C. N., '14, is with the Synthetic Drug Co., 352 Adelaide St. W., Toronto.

Canniff, C. M., '88, lives at 77 St. Clair Ave. E., Toronto.

Carey, B., '89, has no address with us at present.

Carlyle, W. M., '10, is secretary-treasurer of Carlyle and Sons, Ltd., concrete contractors, Toronto.

Carlyle, R. T., '14, is with Carlyle and Sons, Ltd., concrete contractors, 18 Toronto St., Toronto.

Carmichael, R. M., '13. His home address is Kenora, Ont.

Carpenter, H. S., '97, is Superintendent of Highways of the Province of Saskatchewan, Department of Public Works, Regina.

Carrie, G. M., '13, is resident engineer for Chipman and Power, Neepawa, Man. He is in Toronto at present.

Carroll, A. M., '08, is with the Sovereign Construction Company, Toronto.

Carroll, M. J., '06, is with the Department of the Interior, Ottawa, in the Topographical Survey Branch.

Carscallen, H. R., '08, is on hydrographic work in the West, with the Dept. of Interior, Calgary, Alta.

Carson, W. R., '05, is mechanical engineer in charge of plant and construction, Grasseli Chemical Co., Cleveland, O.

Carter, J. M., '14, is with the Nipissing Mines, Cobalt, Ont.

Carter, W. E. H., '98, is a member of the firm of consulting mining engineers, Carter and Smith, Toronto. He is at present at Wilkie, Sask.

Caster, J. H., '07, is with the Hydro-Electric Power Commission of Ontario, Continental Life Building Toronto.

Caudwell, N. S., '10, is taking a course in law at Osgoode Hall.

Cavell, E., '07. His address is 182 Sunnyside Ave., Toronto

Chace, W. G., '01, a member of the firm of Kerry and Chace, Limited, Toronto, is chief engineer of the Greater Winnipeg Water District Winnipeg, Man.

Chadwick, R. E. C., '06, is with the Foundation Company, Limited, Montreal.

Chadwick, W. W., '11, has a manufacturing business at 18 Park St. S., Hamilton, Ont., making electric fixtures, fire-place goods, stampings, turnings, spinnings, and brass goods and metal work of every description.

Challen, G., '08. His address is Chedoke, P.O., Hamilton, Ont.

Challies, J. B., '04, is Superintendent of Water Powers, Department of the Interior, Ottawa.

Chalmers, W. J., '89, is assistant engineer, Ohio River Improvement, U. S. Government, and resides at Vanport, Pa.

Chalmers, J., '94, is city commissioner, Edmonton, Alta.

Chandler, R. B., '11, is with Janse Bros., Boomer, Hughes and Crain, on the construction of the government elevator at Calgary, Alta.

Charlesworth, L. C., '93, resides in Edmonton, and is director of Surveys for the Province of Alberta.

Charlton, H. W., '97, is on the staff of the Experimental Farm, Ottawa, as chemist.

Charlton, O. W. N., '11, formerly with Department of Interior, Ottawa, is now associated with W. T. Haring, general contractor, 100 Washington St., New York, N.Y.

Chase, A. V., '05, whose home is at Orillia, Ont., is on survey work on the Trent Canal.

Cherry, P. G., '11, is advertising salesmanager, Might Directories, Limited, Toronto.

Chestnut, A. W., '10, is at Le Pas, Man., engaged in gold mining.

Chestnut, E. F., '11, is corporal with No. 1 Company, 19th Battalion, 2nd Contingent, at Exhibition Park, Toronto.

Chestnut, F. H., '08, is at Marshfield, Oregon, where he is in business under the name of the Coast Equipment Company, handling engineers equipments and supplies.

Chestnut, V. S., '09, is assistant engineer on the construction of the Welland Ship Canal, St. Catharines, Ont.

Chewett, H. J., '88. His permanent address is Prince George Hotel, Toronto.

Chilver, C. A., '04 is Secretary-Treasurer of C. A. Chilver Co., Limited, Builders' Supplies, Walkerville, Ont.

Chilver, H. L., '04, is assistant engineer, Windsor, Ont.

Chisholm, D. C., 10. We do not know in what line of work he is engaged. He is in Winnipeg Man.

Christie, W., '02, is engaged in engineering and land surveying at Prince Albert, Sask.

Christie, A. G., '01, is Associate Professor of Mechanical Engineering at Johns Hopkins University, Baltimore, Md.

Christie, F., '06, is with the Algoma Central Railway in charge of construction.

Christie, R. M., '14, has 9847-91st Ave., Edmonton, Alta, as his address.

Christie, U. W., '04, is in Ottawa, Ont., in the Astronomical Survey Branch, Department of the Interior.

Chubbuck, L. B., '99, is with the Canadian Westinghouse Co., Hamilton, Ont., in the engineering department.

Clark, F. W., '11, is field engineer, Hydraulic Department, Ontario Hydro-Electric Power Commission, Toronto.

Clark, G. T., '06, is general manager of Richardson Bros., builders and contractors, Saskatoon.

Clark, H. J., '11 is employed on the Burlington, Division, Toronto and Hamilton Highway, Burlington, Ont. His address is 2 Markham St., Wychwood, Toronto.

Clark, H. S., '10, is lieutenant with the 36th Battalion, 3rd Contingent, at Hamilton, Ont.

Clark, H. A., '13, is with the C. P. Ry. near Chapleau, Ont.

Clark, J., '00, was, when last heard from, with the P. and L. E. R. R. at Pittsburgh, Pa., as electrician. We do not know his present address or occupation.

Clarke, F. F., '03, is divisional engineer for the Canadian Northern Railway Co. His home is at 49 Sheldrake Blvd., Toronto.

Clarke, J. E., '11. His home address is 139 Downing Ave., Toronto.

Clarkson, G. E., '13, is with the Parker Dye Works, Ltd., Toronto.

Claveau, J .A., '10, is with the Chicoutini Pulp Co., at Chicoutini, P.Q.

Cleary, F. S., '11. Deceased March 1914.

Clegg, B. D., '13. His home is at 295 Stewart St., Peterborough, Ont.

Clement, S. R. A., '05, is with the Hydro-Electric Power Commission, Toronto, Ont.

Clement, W. A., '89, is city engineer of South Vancouver, B.C.

Clendenning, C. S.. is in the engineering **department Pac.** Gt. Eastern Railway, Quesnel, B.C.

Cline, C. G., '09, is Division Engineer, B.C. Hydrographic Survey, Water Power Branch, Department of Interior, Vancouver, B.C. His address is 249 Hastings St. E., Vancouver, B.C.

Clipsham, K. M., '14, is a member of "Clipsham and Delamere," manufacturers of motor cars, 1896 Dundas St., Toronto.

Clothier, G. A., '99 was, when last heard from at Stewart, B.C., as mining engineer and assayer.

Coates, P. C., '04, when last heard from was teaching at Oakland School, Victoria, B.C. His home was at Violet Ave., Marigold, B.C.

Cockburn, J. R., '01, is Assistant Professor of Drawing in the Faculty of Applied Science and Engineering, University of Toronto.

Cockburn, L. S., '10, is mechanical engineer for Beardmore and Co., Acton, Ont.

Code, A. G., '10, is with the First Canadian Contingent in Europe.

Code, S. B., '04, is town engineer of Smith's Falls, Ont. He has a private practice as civil engineer and surveyor.

Cole, C. R., '10. His home address is Box 606, Woodstock, Ont. We do not know what he is doing at present.

Cole, D. B., '11, formerly Smelter Maintainance Engineer for the Canadian Copper Co., at Copper Cliff, Ont., is now with the Cleveland Cadillac Co., Cleveland, Ohio.

Coleman, J. H., '13, is illuminating engineer for Toronto Electric Light Co., Toronto. His address is 17 Farnham Ave.

Coleman, R. M., '10 is assistant sales manager for the Toronto Electric Light Company, Toronto, Ont.

Colhoun, G. A., '06, is draughtsman for the Hamilton Bridge Works Co., Hamilton, Ont.

Collett, W. C., '08, has a practice as architect at 7 St. Mary St., Toronto.

Collinson, J. G., '09, has St. Thomas Ont., as his home address. He is on the engineering staff on the construction of the Welland Ship Canal.

Collinson, W. G.. '09, is chief chemist for the Carborundum Co., of Niagara Falls, N.Y.

Colquhoun, G. A., '10, is with the Topographical Surveys Branch, Department of the Interior, Ottawa.

Coltham, G. W., '09, is carrying on an engineering and surveying practice at Aurora, Ont.

Connell, C. B. B., '07, is at St. Kitts, B.W.I.

Connor, A. W., '95, is a member of the engineering firm of Bowman and Connor (H. J. Bowman, '85) with offices in Toronto and Berlin, Ont.

Connor, H. V., '02, is with the Canadian Westinghouse Co., Hamilton, Ont.

Cooch, H. A., '09, is sales engineer for the Canadian Westinghouse Co., with headquarters in Toronto.

Cook, A. S., '11, is connected with the Geo. R. Cook Co., contracting engineers. Ford Building, Detroit.

Cook, G. M., '13, is designing engineer for the Trussed Concrete Steel Co., Walkerville, Ont.

Cook, W. A. M., '06, is structural engineer, city architect's department, Toronto.

Coombs, J. A., '13, is at present at 659 Bloor St. W., Toronto.

Coon, B. R., '13, is a member of the firm S. B. Coon and Son, Architects, Ryrie Building, Toronto.

Cooper, C., '99, is at Carlyle, Sask.

Corbould, C. E. B., '14, is assistant engineer, B.C. Hydrographic Survey, Dominion Water Power Branch, Dept. of Interior, Nelson, B.C.

Corman, W. E., '09, is chief draughtsman and assistant engineer on Hydro-Electric work for C. H. and P. H. Mitchell, Traders Bank Building, Toronto.

Cornell, C. W., '11, is a member of the firm, Jones, Cornell Construction Co., Limited, engineers and contractors, New Westminster, B.C.

Corrigan, T. E., '05, is electrical contractor, 34 Begbie St., New Westminster, B.C.